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CLINTON ENGINEER WORKS

CARBIDE AND CARBON CHEMICALS CORPORATION

Y-12 PLANT

CHEMICAL DIVISION

J. M. Herndon

AIR BORNE URANIUM AT Y-12
Third Revised Issue

CHEMICAL DIVISION STAFF
R. G. Berggren

Oak Ridge, Tennessee
September 12, 1947

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The purpose of the tests presented in this report is to detect and correct all conditions hazardous to personnel because of air-borne uranium compounds.

Two hazards occasioned by air-borne uranium compounds are recognized. First, the chemical toxicity of uranium compounds, which hazard is similar to poisoning by other heavy metals. Second, the damage produced by radiations from uranium.

Limits, known as Maximum Allowable Concentrations (MAC), have been established for each of these hazards. The MAC for chemical toxicity has been established as 150 micrograms of uranium per cubic meter of air breathed (150 $\mu g/m^3$) and the MAC for radiation as 1225 alpha particles per minute per cubic meter of air breathed (1225 $\alpha/\text{min } m^3$).

Discussions on and derivations of these figures can be found in "Establishment of a Maximum Allowable Exposure for Alpha-Active Uranium Compounds at Y-12", (appended to this introduction), "SHG Calculations for Alpha Particle MAC for Uranium Bearing Air Borne Dust in Y-12", both by J. W. Morfitt, and other project reports.

When the uranium handled is of isotopic concentrations around that of uranium as occuring in nature and up to approximately 0.05% U234, the MAC for chemical toxicity will be exceeded before the MAC for radiation is reached. This is due to the relatively low alpha emission rate of U238 and U235 (in comparison to U234). Above an isotopic concentration of approximately 0.06% U234 the MAC for radiation will be exceeded before the MAC for chemical toxicity is reached. For this reason the concentrations in this report are given in units of both weight ($\mu g/m^3$) and radiation ($\alpha/\text{min } m^3$) whenever possible.

Appended to this section are two graphs showing the variation in % U234 (W) with respect to time for both Recycle and Product material handled in Y-12.

Section I of this report gives, with one exception, the best average concentration which was applicable to each operating area in the plant before the change to natural feed (July 1, 1947). The exception is in the case of Room 35, Building 9206 for which the figures are for conditions existing with natural feed.

Due both to the change to natural feed and the curtailment of many operations, the radiation levels for most of the areas are now much lower than those listed in this report.

In case there is a high spot concentration in part of the room, this concentration is given as well as the average concentration for the rest of the room. The column headed "Operators Exposure, % Maximum Allowable Concentration" gives the percent of maximum allowable concentration which the operator is actually exposed to including both

[redacted]

general room concentration and high spot concentration. This figure is calculated using the maximum time of exposure to the high concentration. In determining this figure, account was taken of the fact that a short exposure to a concentration over tolerance is worse than the same amount of material breathed over a longer period of time. The concentration was multiplied by $1\frac{1}{2}$ and then averaged on a time of exposure basis with other exposures using a minimum exposure of 1/5 the total working time in cases where time of exposure was less than this. For a more complete discussion of this procedure refer to John Morfitt's memorandum which is appended to this introduction.

Following the data in section one is a short discussion of the conditions in each area.

Section II presents the individual test data which was used in making up Section I.

Section III presents all data which has been gathered by the Chemical Division Staff.

Data presented in this report was obtained by use of the "Filter Queen Air Sampler". This instrument was developed at the University of Chicago for the purpose of determining the amount of Uranium in the air. A few improvements have been made in the equipment as adapted to this plant but the filter medium is still a high grade asbestos base filter paper, H.V. No. 9081, made by Hollingsworth and Vase Co., West Groten, Mass. Tests by the Medical Department at Rochester show an asbestos base filter paper to be superior in collection efficiency to impingement and electrostatic types of collectors as well as other types of filter paper. Tests by the health physics group at Chicago also showed the asbestos base paper described above to be highly efficient.

Improvements made here include a better flowmeter and more sturdy filter holder.

Filters are analysed by counting directly the alpha particles which are emitted by the material deposited on them. The filter is used in tubular form backed by a steel cage like support. This tube is placed in the counter with a probe extending along its axis. The tube is purged with nitrogen and a potential of about 500 volts is applied between the probe and filter. This voltage is set so that a count of 1000 is obtained using a prepared standard tube with an alpha emission of 2800 particles per minute. A blank filter is counted and subtracted from the count of an unknown tube. The only other correction factor is for penetration. The dust particles are imbedded in the filter paper and 30% of the alpha particles emitted are absorbed by the paper. This correction factor was derived by the University of Chicago group. This alpha count may be corrected as above and expressed as alpha particles emitted per minute per cubic meter of air sampled or converted to micro grams (μg) of uranium per cubic meter of air sampled by using specific alpha acitivey data.

In this latter case it is assumed that the material in the air is representative of that handled in the room. In case recycle material is being handled, an average specific alpha activity figure for the week is used. This figure is from process sample assays and usually represents some 90 to 100 samples. Specific alpha activity is expressed as alpha counts per micro gram of uranium per minute on a counter which counts 52% of the particles emitted.

In case of product material, product assay data is used to obtain the specific alpha activity. If all the material handled in an area is the same, a sample can be sent in for assay, but in the case of resolved material of a non-uniform nature, such as carbons, this method of determining weight concentration is not very reliable.

Checks on the above analytical method have been made by the fluorescent method and the results are in close agreement.

Our test results have checked satisfactorily with those obtained by the medical department in the same areas using Mine Safety Appliance's "Dust Foe" respirator worn by operators. Efficiencies of Cottrell Precipitators and large filter installations have been measured and these checked closely with manufactures claims. The amount of material collected by Cottrell Precipitators and large filter installations has been satisfactorily predicted by the methods described above.

R G Berggren

R. G. Berggren
Chemical Division Staff

9-12-47

ESTABLISHMENT OF A MAXIMUM ALLOWABLE EXPOSURE FOR ALPHA-ACTIVE URANIUM COMPOUNDS AT Y-12

John W. Morfitt

Y-12 Special Hazards Group

ESTABLISHMENT OF A MAXIMUM ALLOWABLE EXPOSURE FOR ALPHA-ACTIVE URANIUM COMPOUNDS AT Y-12

The problem of alpha radioactivity in Y-12 has only recently been viewed as a potential health hazard. The reasons for this should be made clear before proceeding with the remainder of this report.

Uranium compounds, as we know them in Y-12, can have two harmful effects on the body: 1. simple chemical poisoning, similar to that produced by lead; 2. tissue or cell damage which may result from the compounds' radioactivity, analogous to the effects produced by small amounts of radium. Each of these has its own tolerance dose*, depending on the material involved, the most vulnerable organ and the method by which the material enters the body. In this discussion of uranium compounds, the penetration of alpha or beta particles or quanta into the body can be neglected. The outer layer of skin is thick enough to harmlessly absorb all (uranium) alpha particles and beta particles up to energies of 0.2 Mev. Beta particles of higher energies, such as UX_2 (2.32 Mev energy)[17], penetrate about 1 cm into the skin and could cause only local effects, even if present in large amounts.

The gamma intensity of an infinite slab of uranium in equilibrum with its daughter products (the maximun possible under plant conditions) is about .005 roentgens per hour[13] at the surface of the metal (40% of tolerance). The effect of general body irradiation is of secondary importance compared to the alpha particle hazard.

There are three principal ways in which uranium compounds can enter the body; ingestion, inhalation, and incision (skin puncture). For uranium, the potential radiation and chemical hazard is greatest for the lungs[1,14]. Therefore, our chief concern is for the maximum allowable concentration <u>in the air</u>. For some time the <u>chemical</u> m.a.c. in air has been established as 150 micrograms per cubic meter [14,15,12]. At the time this value was established for chemical tolerance, the value reported for radioactive m.a.c. was 10^{-8} curies/cubic meter,[12,5,6], a value used for radon based on studies made of lung cancer in workers in pitchblende mines. On this assumption, it can be shown that a concentration of 150 $\mu g/m^3$ of natural uranium would contribute only .001 of the alpha particles necessary to produce radioactive tolerance, and even product level material (Dec. 1945) in concentrations of 150 $\mu g/m^3$ would still be below (94%) the radioactive m.a.c. Tests of air contamination made throughout 1946 [9] showed uranium concentrations which were only a fraction of the 150 µg limit, usually below 1 $\mu g/m^3$ and seldom above 10. The highest value for room contamination this office has any record of up to the 9212 investigation is 24.5 $\mu g/m^3$ in 9204-3 [16].

* The tolerance dose for a given period will be defined as that amount of material or radiation to which the body can be subjected over that given period without the production of harmful effects. Radiologists and health physicists have come to regard such value as a "maximum allowable" rather than a "tolerance" figure. Accordingly, the currently accepted term for "tolerance dose" is "maximum allowable exposure" (m.a.e.) and the amount of material producing such an exposure is called the "maximum allowable concentration" (m.a.c.)[6]. The terms "tolerance" concentration and "maximum allowable" concentration are used interchangeably in this report.

The advent of K-25 material into the cycle brought with it a higher percentage of the U-234 isotope* than is predicted by assuming a constant U-235/U-234 enhancement factor, but this increased W was expected, and was no cause for worry except for its effect on analytical procedures. Because of this latter fact, however, Y-12 has reliable information as to the U-234 content of the recycle material throughout 1946. The radioactive m.a.c. of 10^{-8} cu/m^3 was given officially [12] on April 24, 1946, and the Project Handbook[5] still lists this as the only value for alpha radiation in the lungs.

It was not until results were obtained from work on the Plutonium Project [1,2,3] that it was realized that the m.a.c. for a gaseous material like radon and a radioactive dust is of a different order of magnitude. The radioactive m.a.c. previously used in Y-12 had to be abandoned.

A request from Mr. J. L. Patterson on November 15, to investigate the hazards from higher U-234 concentrations than had yet been encountered in Y-12 and the assignment by Dr. Conklin on November 29 of the Special Hazards Group to act as a clearing house on all radioactive problems, started a series of investigations. This resulted in the establishment on December 2, 1946, of a tentative radioactive m.a.c., calculated by the group from what are believed to be the best data available. This value whose calculation is described in more detail below was used to estimate the 9212 hazards in a report of December 11, 1946[10], and subsequent reports. It was given verbal approval[14] by the Y-12 Medical Department and by Dr. J. H. Sterner of the Advisory Board on January 21, 1947. The remainder of this report discusses the factors taken into consideration in establishing this level.

The ionization occurring in a small volume "element" in an absorbing medium being subjected to radiation is approximately proportional to the energy absorbed per unit volume. If air is the absorbing medium, the roentgen, a radiation unit, may be defined as that quantity of X or gamma radiation which liberates one e.s.u. per c.c. of air[5,6]. For X-rays, the energy absorbed per gram of soft tissue is approximately equal to that absorbed per gram of air. This corresponds to a (measured) energy absorption of 83 ergs per gram of tissue[6]. The "roentgen equivalent physical" (rep) is this modified definition of the roentgen applied to all types of radiation, including alphas, betas, and neutrons. The mrep is 0.001 rep.

According to Dr. K. Z. Morgan, the value of 10 mrep for alpha particles is used by most of the laboratories in the Manhattan District. It is the basis of calculations made in Y-12.

From this[8] value of the tolerance energy absorbed per gram of lung tissue, (10 mrep) the energy of the emitted particle (4.27 Mev), the half-life of the element (assumed to be infinite), the biological half-life (2 months), and the time a person is considered to be exposed to this element (assumed to be infinite), we can calculate the maximum allowable rate in curies per second at which this element can be concentrated in the lungs (4.97×10^{-9}). From this fact and the

*U-234 is about 9,500 as active as natural uranium and about 3000 times as active as pure U-235.

breathing rate, (150 cc/sec), we can calculate the maximum allowable concentration in the air of the room, assuming all the material in the air gets into the lungs (3.3×10^{-11} $\mu c/cc$). Since only a fraction of the dust in the room is assumed to enter the lungs ("biological utilization" = 25%), it follows that the air may contain 1/.25 times as much dust as would otherwise be possible. Furthermore, since the calculations are based on continuous exposure, an operator exposed 40 hours per week can be subjected to an m.a.c. of 168/40 = 4.2 times as great. Conversion of units ($\mu c/cc$ to α's/min/m^3) by means of the definition of the curie ($3.68 \times 10^{10} \times 60$ α's/min) gives the desired result of 1225 * alpha particles per cubic meter per minute.

The calculation is a straightforward application of methods developed by Dr. K. Z. Morgan at X-10 [1]. The conservatism lies in the original assumption of 10 mrep for alpha m.a.c. rather than in any artibrary treatment of the attendant calculations.

The units given are chosen so as to be independent of the isotopic concentration since the energies of the emitted alphas are almost indentical for the three isotopes. The units are also chosen so that results of Filter Queen tests can be interpreted with the smallest number of mathematical operations.

In respirator tests, it is often more convenient to compare the micrograms of uranium obtained per cubic meter of air with the m.a.c. expressed on a weight basis. The m.a.c. (weight basis) will, of course, vary with the specific activity. A graph, plotting this relationship is attached to this report. The only caution that need be given is that the specific activity must be expressed in terms of a full (4π) solid angle. If the laboratory report is given for a half solid angle their value should be multiplied by two before looking up the corresponding m.a.c. on the graph.

The Special Hazards Group therefore recommends the adoption of 1225 α's/min/m^3 as the m.a.c. for uranium-bearing dust in Y-12.

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* It is not claimed that this figure is accurate beyond two significant figures.

1-31-47

Signed by John W. Morfitt
Special Hazards Group

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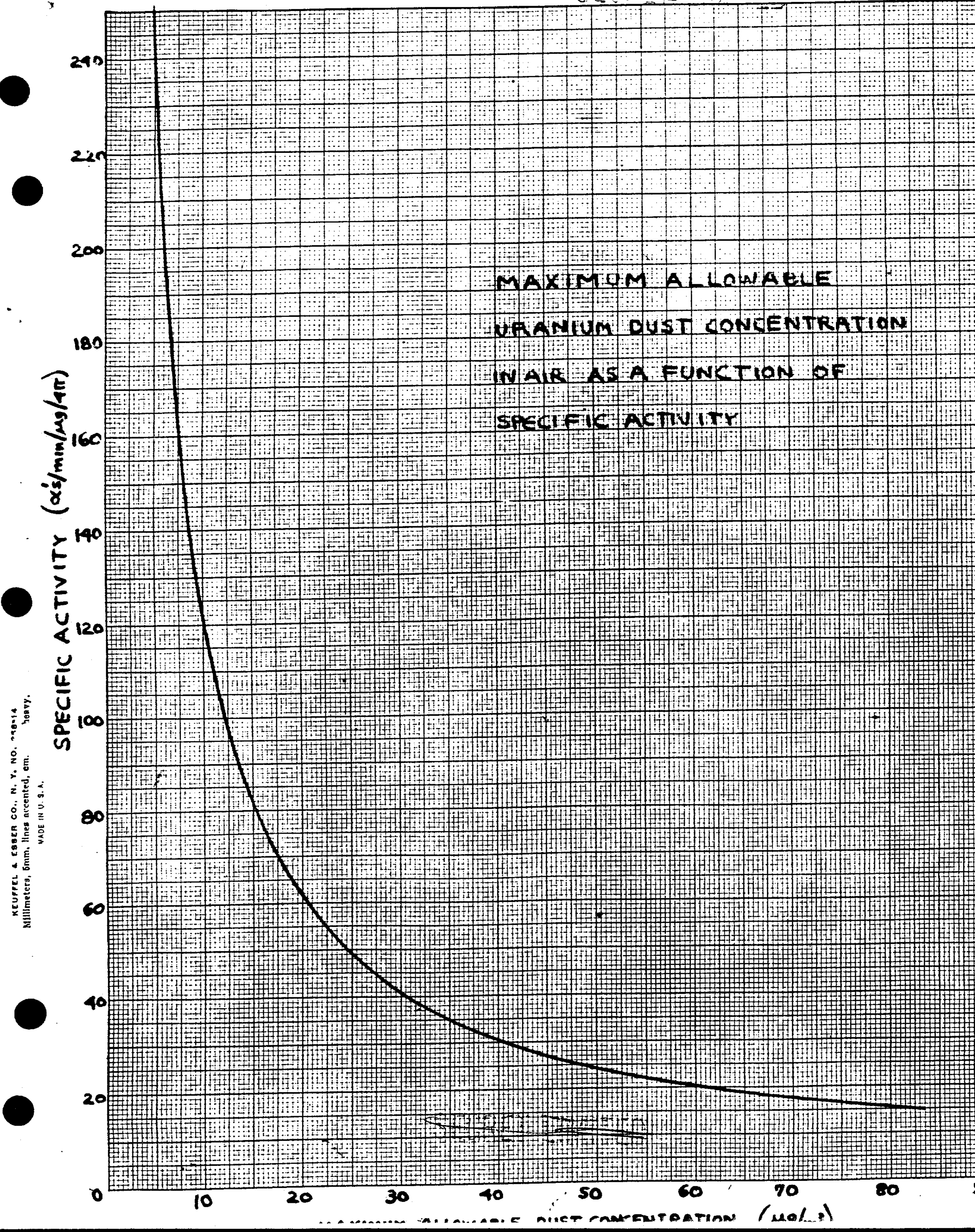
MAXIMUM ALLOWABLE
URANIUM DUST CONCENTRATION
IN AIR AS A FUNCTION OF
SPECIFIC ACTIVITY
SPECIFIC ACTIVITY (α's/min/μg/4π)
240
220
200
180
160
140
120
100
80
60
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10
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50
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ALLOWABLE DUST CONCENTRATION
KEUFFEL & ESSER CO., N. Y. NO. 358-14
Millimeters, 5mm. lines accented, cm. heavy.
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In considering what procedure should be used in calculating the integrated exposure an operator would receive when exposed to relatively high alpha concentrations for short periods of time, the following points should be considered.

a. The time-concentration relationship cannot be considered linear since very high intensity radiation can be fatal even for extremely brief periods of exposure.

b. The safety factor for the value being used is not thought to be more than two or three and this allows little leeway for occasional errors in contamination measurement and no leeway at all for the occasional person (one in 1000) who is especially sensitive to radiation.

c. The person who has received an overdose of radiation in a short time can, by avoiding further exposure, bring his dosage rate down to "tolerance"; but in the meantime, he has been subjecting his body to a continuous overdose of radiation. A person receiving 3 r in one day, will in a month be back to "normal", if no further exposure occurs; but after the first ten days, his averaged integrated exposure to date has been over 8.7 times tolerance.

d. Certain undesirable physiological effects are thought to occur even below the presently established "tolerance" and most health physicists think in terms of maximum allowable exposure, rather than as "tolerance" exposure.

With these facts the following rules are proposed for calculation of operator exposure.

1. When the air contamination is below the mac ($1225\alpha/sec/m^3$) value, operator exposures shall be calculated as a linear proportion.

2. When the air contamination is above the mac, the actual air concentration shall be multiplied by a factor of $1\frac{1}{2}$ and the operator exposure calculated as a linear proportion as before, except as in #3 below.

3. In no case will the time of exposure be considered to be less than 1/5 of the total working time.

4. When an operator receives radiation from more than one source, each exposure is calculated as if it existed separately and the results added.

Example 1:

An operator is in a room for 3 hours a day where the air contamination is 2000 $\alpha/min/m^3$. Calculate the relative exposure if the operator receives no other dust exposure.

The alpha level is above tolerance level so it is multiplied by $1\frac{1}{2}$. The tolerance is then calculated as a straight proportion.

$$2000 \times 1\tfrac{1}{2} \times 3/8 \times 1/1225 = 92\% \text{ of tolerance.}$$

Example 2:

An operator works in a room 4 hours per day, during every third week, where the room concentration is 4000 α/min/m^3; and the rest of the working time in a room where the concentration is 75 α/min/m^3. What is the relative exposure?

The operator's average time per day (per 3 week period) spent in the first area is

$$\frac{4}{8 \times 3} = \frac{1}{6} \text{ of working time.}$$

This is less than 1/5 of working time so 1/5 is used instead (Rule 3).

$$3500 \times 1\tfrac{1}{2} \times 1/5 \times 1/1225 = .857 \text{ of tolerance PLUS}$$

the second exposure, which being below tolerance, is calculated linearly.

$$75 \times 5/6 \times 1/1225 = .051.$$

Total exposure $.857 + .051 = 90.8\%$ of tolerance.

It is felt that this method of calculatinn, while somewhat arbitrary, is justified by the fact that it provides an extra factor of conservatism for those operators who may be subjected to intermittent over-tolerance bursts of radiation.

Signed by John W. Morfitt
Special Hazards Group
2-28-47

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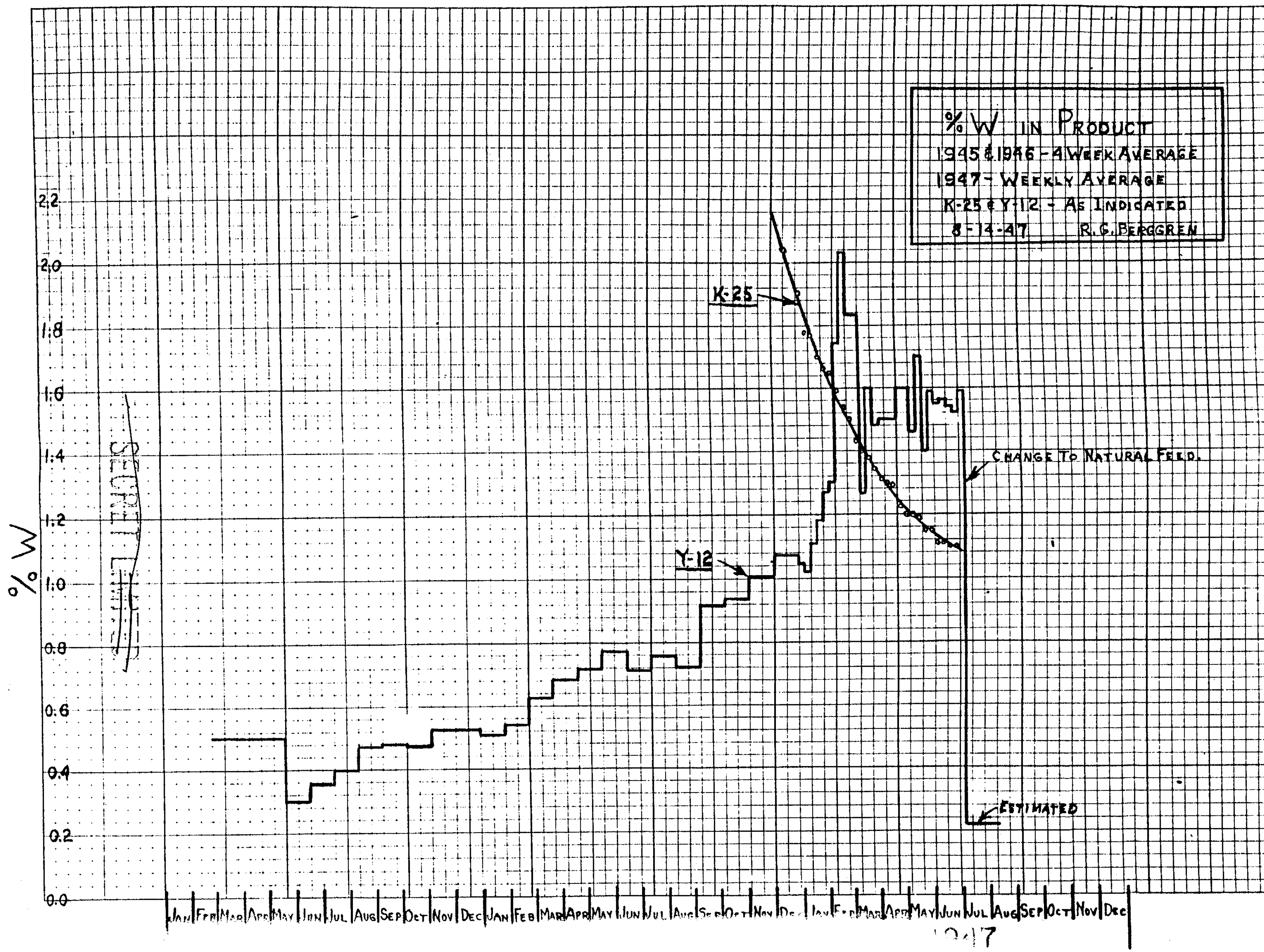

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